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(54) **SHAPE MEMORY ALLOY BASED LINEAR ACTUATOR ASSEMBLY**

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H01H 71/18	(2006.01)
F03G 7/06	(2006.01)

(52) **U.S. Cl.**

CPC . ***F03G 7/065*** (2013.01); ***F03G 7/06*** (2013.01)

(58) **Field of Classification Search**

CPC F03G 7/06; F03G 7/065; F16K 31/00
USPC 60/527–529
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,404,098	B1 *	6/2002	Kayama et al.	310/307
6,762,515	B2	7/2004	Gummin et al.	
6,832,477	B2	12/2004	Gummin et al.	
7,555,900	B1	7/2009	Vallance et al.	
7,723,896	B2 *	5/2010	Esashi et al.	310/306

OTHER PUBLICATIONS

Jose R. Santiago Anadon, “Large Force Shape Memory Alloy Linear Actuator”, Thesis presented to University of Florida, 2002.

* cited by examiner

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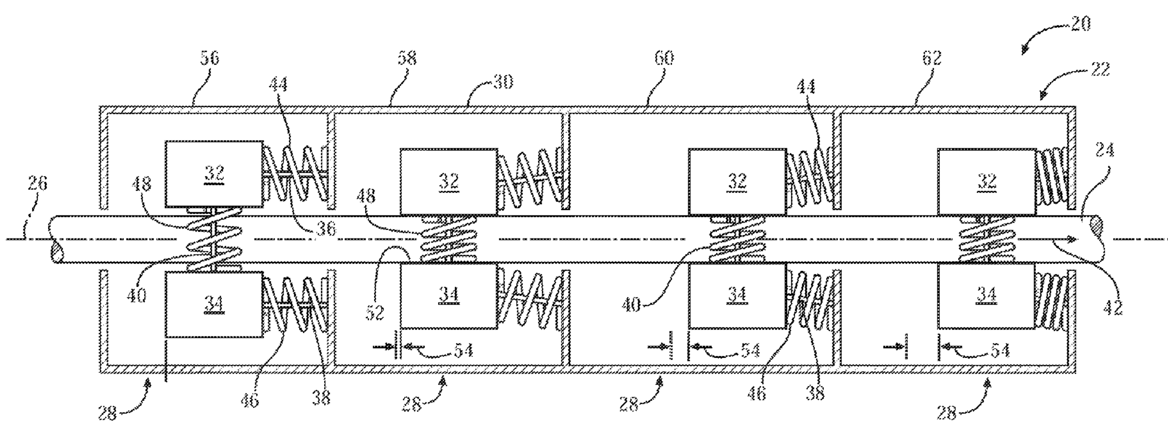
(57) **ABSTRACT**

A linear motion device includes a rod extending along a longitudinal axis, and a plurality of actuator units. Each of the plurality of actuator units includes at least one Shape Memory Alloy (SMA) element that is attached to a coupling mechanism. The at least one SMA element of each if the plurality of actuator units moves the coupling mechanism along the longitudinal axis, and into grasping engagement with the rod. Each actuator unit moves the rod a unit movement distance along the longitudinal axis in response to a control signal. The plurality of actuator units are actuated repeatedly in a cyclic order to move the rod in a continuous linear motion a distance greater than the unit movement distance of each of the plurality of actuator units.

17 Claims, 3 Drawing Sheets



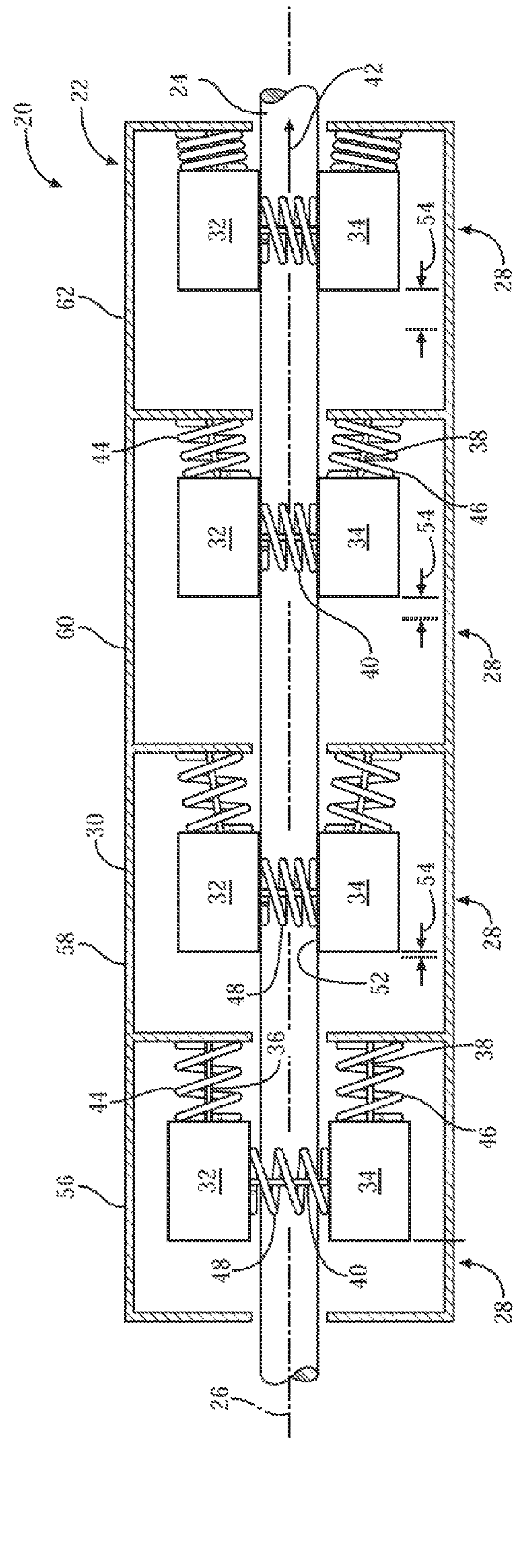


FIG. 1

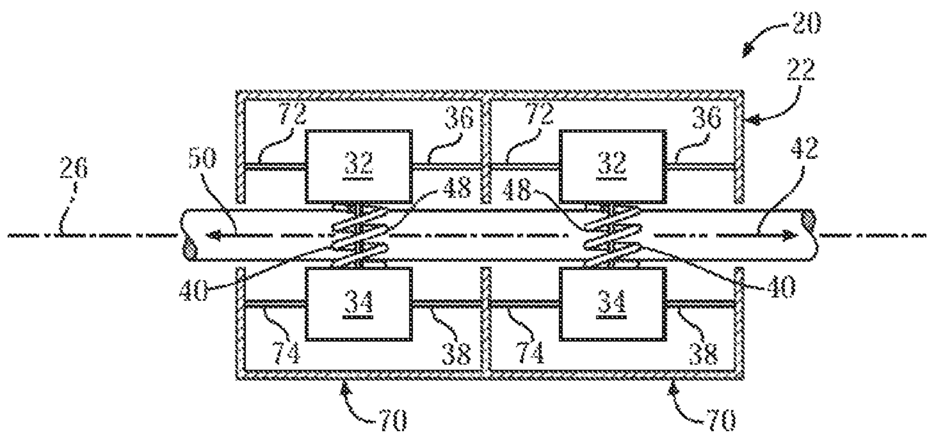

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FIG. 2

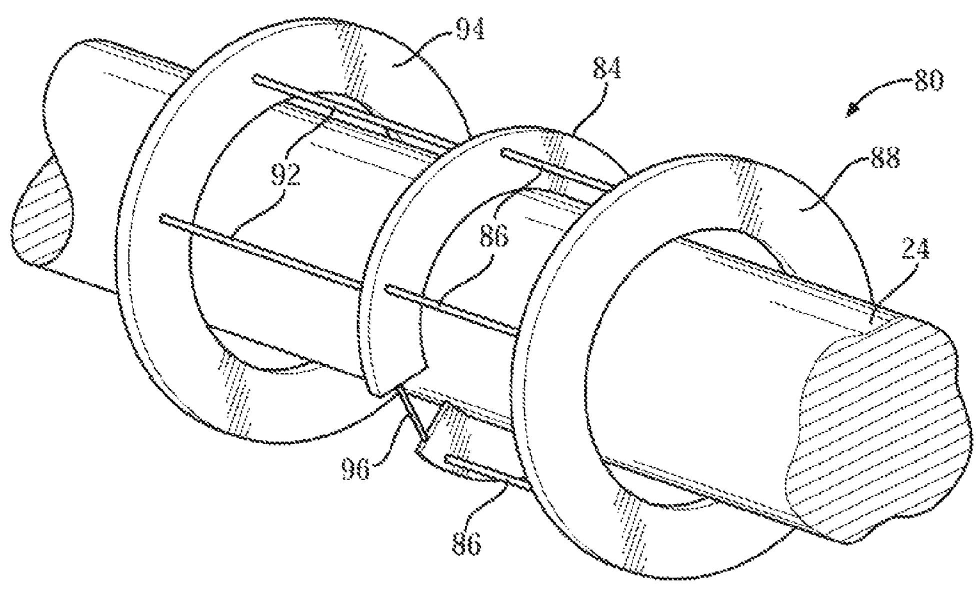
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FIG. 3

FIG. 4

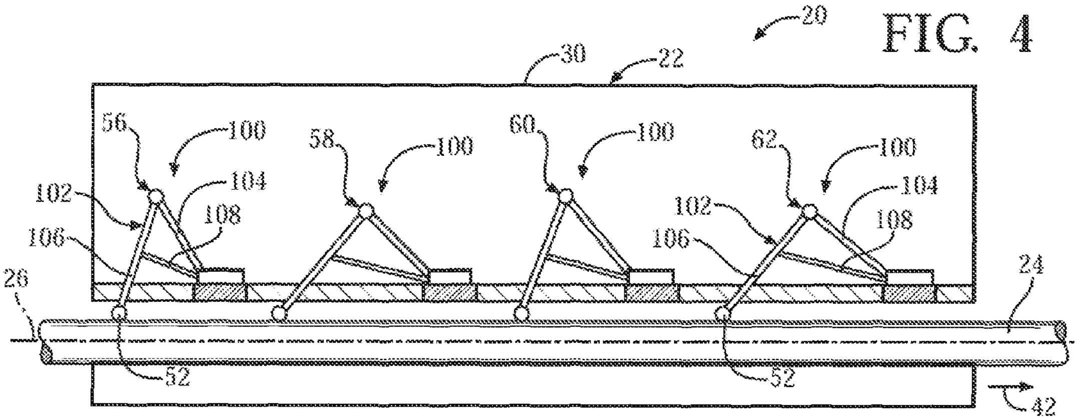
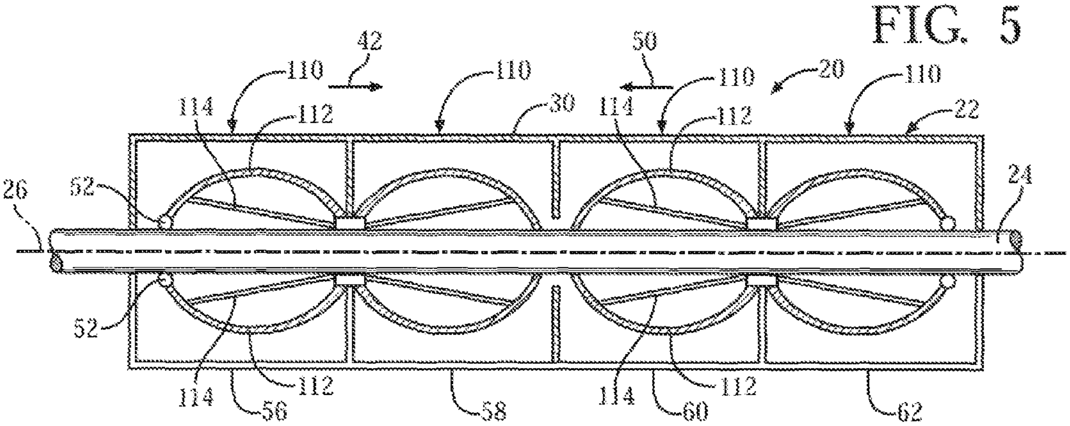


FIG. 5



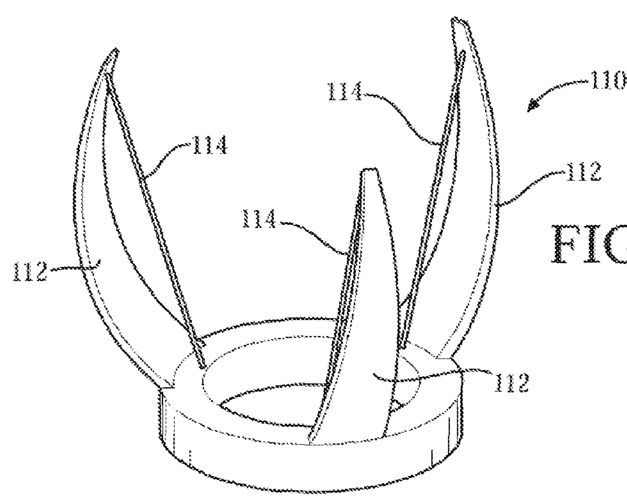


FIG. 6

SHAPE MEMORY ALLOY BASED LINEAR ACTUATOR ASSEMBLY

TECHNICAL FIELD

The invention generally relates to a linear actuator assembly for a linear motion device.

BACKGROUND

Many linear actuators exist for moving a rod along a linear path. Some linear actuators utilize a Shape Memory Alloy (SMA) element to linearly move the rod. The SMA element contracts in response to a control signal, such as an electric current to move the rod. When the electric current is interrupted, the SMA element cools, and returns, i.e., elongates to an initial, pre-contracted length. The length of the SMA element may decrease up to approximately 5% of the initial length of the SMA element during contraction. The actual decrease in length of the SMA element is dependent upon the heating temperature of the SMA element. Accordingly, the distance the SMA based linear actuators may move the rod is limited to approximately 5% of the length of the SMA element.

SUMMARY

A linear motion device is provided. The linear motion device includes a rod extending along a longitudinal axis, and a plurality of actuator units. Each of the plurality of actuator units includes at least one Shape Memory Alloy (SMA) element that is attached to a coupling mechanism. The at least one SMA element of each of the plurality of actuator units moves the coupling mechanism along the longitudinal axis and into grasping engagement with the rod. Each actuator unit moves the rod a unit movement distance along the longitudinal axis in response to a control signal. The plurality of actuator units are actuated repeatedly in a cyclic order to move the rod in a continuous linear motion a distance greater than the unit movement distance of each of the plurality of actuator units.

A linear actuator assembly for a linear motion device is also provided. The linear actuator assembly includes a plurality of actuator units. Each of the actuator units includes a housing, a coupling mechanism, and at least one Shape Memory Alloy (SMA) element attached to the coupling mechanism. The at least one SMA element moves the coupling mechanism from a neutral position, along a longitudinal axis, and into grasping engagement with a rod. The linear actuator assembly moves the rod a unit movement distance along the longitudinal axis in response to a control signal applied to the SMA element. The at least one SMA element of each of the plurality of actuator units contracts in response to the control signal to move the coupling mechanism. The at least one SMA element of each of the plurality of actuator units shortens in response to the cessation of the control signal, to release the coupling mechanism from the grasping engagement with the rod and allow the coupling mechanism to return to the neutral position. The plurality of actuator units are actuated repeatedly in a synchronized order to move the rod in a continuous linear motion a distance greater than the unit movement distance of each of the plurality of actuator units.

Accordingly, the linear actuator assembly uses a plurality of SMA based linear actuator units to move the rod in a continuous, smooth, un-interrupted motion. The movement of the rod is not limited to the individual unit movement distance of each of the individual SMA elements, because the plurality of actuator units are actuated repeatedly in the synchronous order. Accordingly, movement of the rod is limited only by the length of the rod.

The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan view of a linear motion device showing a linear actuator assembly having a plurality of actuator units.

FIG. **2** is a schematic plan view of a first alternative embodiment of one of the plurality of actuator units.

FIG. **3** is a schematic perspective view of a second alternative embodiment of one of the plurality of actuator units.

FIG. **4** is a schematic plan view of the linear motion device showing the linear actuator assembly with a third alternative embodiment of the plurality of actuator units.

FIG. **5** is a schematic plan view of the linear motion device showing the linear actuator assembly with a fourth alternative embodiment of the plurality actuator units.

FIG. **6** is a schematic perspective view of the fourth alternative embodiment of one of the plurality of actuator units.

DETAILED DESCRIPTION

Those having ordinary skill in the art will recognize that terms such as "above," "below," "upward," "downward," "top," "bottom," etc., are used descriptively for the figures, and do not represent limitations on the scope of the invention, as defined by the appended claims.

Referring to the Figures, wherein like numerals indicate like parts throughout the several views, a linear motion device is generally shown at **20**. Referring to FIG. **1**, the linear motion device **20** includes a linear actuator assembly **22** that moves a rod **24** along a linear path defined by a longitudinal axis **26** of the rod **24**.

The linear actuator assembly **22** includes a plurality of actuator units **28**. Each of the actuator units **28** may include a housing **30**, and at least one Shape Memory Alloy (SMA) element. Alternatively, the linear actuator assembly **22** may include a single housing **30** supporting the plurality of actuator units **28** therein. The SMA element is attached to a coupler, hereinafter referred to as a coupling mechanism, and connects the coupling mechanism to the housing **30**. In response to a control signal, the SMA element of each if the actuator units **28** moves the coupling mechanism along the longitudinal axis **26**, and into grasping engagement with the rod **24** to move the rod **24** along the longitudinal axis **26**. The rod **24** and the coupling mechanism are both moveable relative to the housing **30**.

As shown in FIG. **1**, each of the actuator units **28** includes a first coupler, hereinafter referred to as a first coupling mechanism **32**, and a second coupler, hereinafter referred to as a second coupling mechanism **34**. However, it should be appreciated that the actuator units **28** may be configured to include only a single coupling mechanism. The first coupling mechanism **32** and the second coupling mechanism **34** are disposed on opposite sides of the rod **24**. Additionally, each of the actuator units **28** shown in FIG. **1** includes a first SMA element **36** coupled to and interconnecting the first coupling mechanism **32** and the housing **30**, a second SMA element **38** coupled to and interconnecting the second coupling mechanism **34** and the housing **30**, and a connecting SMA element **40** extending between and attached to both the first coupling mechanism **32** and the second coupling mechanism **34**. The first SMA element **36** and the second SMA element **38** contract in response to the control signal to move the first coupling mechanism **32** and the second coupling mechanism **34** in a first direction **42** parallel with the longitudinal axis **26**. The connecting SMA element **40** contracts in response to the control signal to draw the first coupling mechanism **32** and the second coupling mechanism **34** together into grasping engagement with the rod **24**.

Each of the actuator units **28** includes at least one spring, hereinafter referred to generically as a biasing device. The biasing device biases against the coupling mechanism to urge the coupling mechanism into the neutral position. As shown in FIG. **1**, each of the actuator units **28** includes a first spring, hereinafter referred to as a first biasing device **44**, coupled to and interconnecting the first coupling mechanism **32** and the housing **30**, a second spring hereinafter referred to as a second biasing device **46**, coupled to and interconnecting the second coupling mechanism **34** and the housing **30**, and a connecting spring, hereinafter referred to as a connecting biasing device **48**, extending between and attached to both the first coupling mechanism **32** and the second coupling mechanism **34**. The first biasing device **44** and the second biasing device **46** bias the first coupling mechanism **32** and the second coupling mechanism **34** respectively against the housing **30** to move the first coupling mechanism **32** and the second coupling mechanism **34** in a second direction **50** parallel with the longitudinal axis **26**, which is opposite the first direction **42**. Accordingly, in response to the cessation or interruption of the control signal, and the resultant cooling and elongation of the first SMA element **36** and the second SMA element **38**, the first biasing device **44** and the second biasing device **46** move the first coupling mechanism **32** and the second coupling mechanism **34** back into a neutral position as the first SMA element **36** and the second SMA element **38** elongate. The connecting biasing device **48** biases the first coupling mechanism **32** and the second coupling mechanism **34** against each other and away from each other. Accordingly, in response to the cessation or interruption of the control signal, and the cooling and elongation of the connecting SMA element **40**, the connecting biasing device **48** moves the first coupling mechanism **32** and the second coupling mechanism **34** out of grasping engagement with the rod **24** and back into the neutral position.

At least one of the rod **24**, the first coupling mechanism **32** and/or the second coupling mechanism **34** may include a friction feature **52**. The friction feature **52** operates to increase friction between the rod **24** and at least one of the first coupling mechanism **32** and the second coupling mechanism **34**. The friction feature **52** may include serrations, ridges, abrasive material, non-slip material, etc., formed into or attached to one of the rod **24**, the first coupling mechanism **32**, and/or the second coupling mechanism **34**.

Actuation of the SMA element of each actuator unit **28** is capable of moving the rod **24** a unit movement distance **54**. Accordingly, each individual actuator unit **28** is capable of moving the rod **24** a distance equal to the unit movement distance **54**. The unit movement distance **54** of each actuator unit **28** may include a distance equal to approximately 5% of a total length of the SMA element of each actuator unit **28**.

The SMA element moves the coupling mechanism in response to the control signal, such as but not limited to an electrical current applied to the SMA element. The control signal heats the SMA element, causing the SMA element to change forms and contract, as described in greater detail below. The SMA element of each of the actuator units **28** contracts in response to the control signal to move the coupling mechanism from the neutral position into grasping engagement with the rod **24**, and to move the coupling mechanism along the longitudinal axis **26** to move the rod **24** the unit movement distance **54**. The SMA element of each of the actuator units **28** elongates in response to the cessation of the control signal. Upon the cessation of the control signal, the SMA element cools, causing the SMA element to change forms and elongate or lengthen, as described in greater detail below. The elongation of the SMA element releases the coupling mechanism from the grasping engagement with the rod **24**, and allows the coupling mechanism to return to a neutral position.

The plurality of actuator units **28** are actuated repeatedly in a synchronous and/or cyclic order to move the rod **24** in a continuous linear motion a distance that is greater than the unit movement distance **54** of each of the plurality of actuator units **28**. As used herein, the term synchronous is defined as occurring at the same time, and the term cyclic is defined as recurring in cycles. Accordingly, it should be appreciated that the actuator units **28** operate simultaneously at the same time in a repeated cycle to move the rod **24**. The cyclic order may occur, for example, when a control signal is applied to a first actuator unit **56**, thereby causing the SMA element of the first actuator unit **56** to contract, which moves the coupling mechanism of the first actuator unit **56** into grasping engagement with the rod **24** and moves the rod **24** along the longitudinal axis **26**. Prior to the first actuator unit **56** moving the complete unit movement distance **54**, a control signal is applied to a second actuator unit **58**, thereby causing the SMA element of the second actuator unit **58** to contract, which moves the coupling mechanism of the second actuator unit **58** into grasping engagement with the rod **24** and moves the rod **24** along the longitudinal axis **26**. Once the second actuator unit **58** is disposed in grasping engagement with the rod **24** and is moving the rod **24** along the longitudinal axis **26**, the control signal to the first actuator unit **56** is interrupted, thereby causing the coupling mechanism of the first actuator unit **56** to disengage the rod **24** and return to the neutral position of the first actuator unit **56**.

Prior to the second actuator unit **58** moving the complete unit movement distance **54**, a control signal is applied to a third actuator unit **60**, thereby causing the SMA element of the third actuator unit **60** to contract, which moves the coupling mechanism of the third actuator unit **60** into grasping engagement with the rod **24** and moves the rod **24** along the longitudinal axis **26**. Once the third actuator unit **60** is disposed in grasping engagement with the rod **24** and is moving the rod **24** along the longitudinal axis **26**, the control signal to the second actuator unit **58** is interrupted, thereby causing the coupling mechanism of the second actuator unit **58** to disengage the rod **24** and return to the neutral position of the second actuator unit **58**.

FIG. **1** further shows a fourth actuator unit **62** that operates in the same manner following the third actuator unit **60**. Upon all of the actuator units **28** cycling through the synchronous and cyclic order described above, the cyclic order is repeated. In so doing, prior to the fourth actuator unit **62** moving the complete unit movement distance **54**, a control signal is applied to the first actuator unit **56**, thereby causing the SMA element of the first actuator unit **56** to contract, which moves the coupling mechanism of the first actuator unit **56** into grasping engagement with the rod **24** and moves the rod **24** along the longitudinal axis **26**. Once the first actuator unit **56** is disposed in grasping engagement with the rod **24** and is moving the rod **24** along the longitudinal axis **26**, the control signal to the fourth actuator unit **62** is interrupted, thereby causing the coupling mechanism of the fourth actuator unit **62** to disengage the rod **24** and return to the neutral position of the fourth actuator unit **62**. It should be appreciated that the linear actuator assembly **22** may include any number of actuator units **28** required to allow each of the SMA elements to cool so that the coupling mechanism of each actuator unit **28** may return to the neutral position prior to being actuated again in the repeated cyclic order described above.

The actuator units **28** may be configured to default to a normally engaged position, in which the actuator units **28** are engaged in grasping engagement with the rod **24**, or may be configured to default to a normally disengaged position, in which the actuator units **28** are not engaged in grasping engagement with the rod **24**. If the actuator units **28** default to the normally engaged position, then activation of the SMA elements will release the actuator units **28** from engagement with the rod **24**. In contrast, if the actuator units **28** default to the normally disengaged position, then activation of the SMA elements will cause the actuator units **28** to engage the rod **24**.

Referring to FIG. **2**, a first alternative embodiment of an actuator unit is generally shown at **70**. The at least one SMA element of each of the plurality of actuator units **28** is configured to move the coupling mechanism and the rod **24** in both the first direction **42** and the second direction **50**. In addition to the first SMA element **36** attached to the first coupling mechanism **32**, and the second SMA element **38** attached to the second coupling mechanism **34**, the at least one SMA element of the actuator unit **70** includes a third SMA element **72** attached to the first coupling mechanism **32**, and a fourth SMA element **74** attached to the second coupling mechanism **34**. The first SMA element **36** and the second SMA element **38** contract in response to the control signal to move the first coupling mechanism **32** and the second coupling mechanism **34** in the first direction **42**. The third SMA element **72** and the fourth SMA element **74** contract in response to a control signal to move the first coupling mechanism **32** and the second coupling mechanism **34** in the second direction **50**. By including the third SMA element **72** and the fourth SMA element **74**, the actuator unit **70** eliminates the need for the first biasing device **44** and the second biasing device **46** described above.

Referring to FIG. **3**, a second alternative embodiment of one of the actuator units is generally shown at **80**. The actuator unit **80** is configured to act on a rod **24** having a circular cross section perpendicular to the longitudinal axis **26** of the rod **24**. The actuator unit **80** includes a coupling mechanism **84** having a generally C-shaped configuration disposed about an outer periphery of the rod **24**. The C-shaped coupling mechanism **84** includes and/or is manufactured from a spring material that is biased to expand radially outward. The at least one SMA element includes a plurality of first SMA elements **86** connecting the C-shaped coupling mechanism **84** to a first end **88** of a housing **30**, and a plurality of second SMA elements **92** connecting the C-shaped coupling mechanism **84** to a second end **94** of the housing **30**. A connecting SMA element **96** connects the open ends of the C-shaped coupling mechanism **84**.

In response to a control signal, the first SMA elements **86** and/or the second SMA elements **92** act to move the C-shaped coupling mechanism **84** in either the first direction **42** or the second direction **50** as described above. Additionally, in response to the control signal, the connecting SMA element **96** contracts to draw the open ends of the C-shaped coupling mechanism **84** together, bringing the coupling mechanism **84** into grasping engagement with the rod **24**. Upon the cessation or interruption of the control signal and the resultant cooling and elongation of the connecting SMA element **96**, the spring force of the C-shaped coupling mechanism **84** expands the coupling mechanism **84** radially outward to disengage the grasping engagement between the coupling mechanism **84** and the rod **24**.

Referring to FIG. **4**, a third alternative embodiment of the plurality of actuator units is generally shown at **100**. Each actuator unit **100** includes a lever arm **102** having a first member **104** attached to the housing **30**, and a second member **106** cantilevered from the first member **104**. An SMA element **108** is attached to and interconnects the second member **106** of the lever arm **102** and the housing **30**. Contraction of the SMA element **108** moves a distal end of the second member **106** in the first direction **42** and into grasping engagement with the rod **24**. Accordingly, the lever arm **102** of the actuator units **100** increase the strength applied to the rod **24**, with a decrease in the movement speed of the rod **24**.

The plurality of actuator units **28** may be defined by groups of actuator units **28** that work simultaneously with each other, with the groups of actuator units **28** following the repeated cyclic order described above. The linear actuator assembly **22** shown in FIG. **4** includes a first actuator unit **56**, a second actuator unit **58**, a third actuator unit **60** and a fourth actuator unit **62**. The plurality of actuator units **28** may include a first group and a second group. For example, the first group may include the first actuator unit **56** and the third actuator unit **60**, and the second group may include the second actuator unit **58** and the fourth actuator unit **62**. Each of the actuator units **28** in the different groups of actuator units **28** may be actuated simultaneously to increase a moving force applied to the rod **24**. For example, the first group may be actuated simultaneously to engage and move the rod **24**, and prior to the first group moving the rod **24** the unit movement distance **54**, the second group of actuator units **28** may be actuated to engage and move the rod **24**. Accordingly, the use of multiple actuator units **28** simultaneously increases the overall force applied to move the rod **24**. It should be appreciated that the number of actuator units **28** in each group, and the number of groups of actuator units **28** may differ from the exemplary embodiment described above.

Referring to FIGS. **5** and **6**, a fourth alternative embodiment of the plurality of actuator units is generally shown at **110**. Each actuator unit **110** includes a plurality of spring arms **112** connected to the housing **30** by an SMA element **114**. In response to the control signal, each of the SMA elements **114** contract, drawing a distal end of each respective spring arms **112** into grasping engagement with the rod **24** and moving the distal end of the spring arms **112** along the longitudinal axis **26**. The plurality of actuator units **110** may include a first group and a second group, with the first group configured to move the rod **24** in the first direction **42**, and the second group configured to move the rod **24** in the second direction **50**. As shown in FIG. **5**, the plurality of actuator units **110** includes a first actuator unit **56**, a second actuator unit **58**, a third actuator unit **60** and a fourth actuator unit **62**. The first actuator unit **56** and the third actuator unit **60** define the first group for moving the rod **24** in the first direction **42**, and the second actuator unit **58** and the fourth actuator unit **62** define the second group for moving the rod **24** in the second direction **50**.

The SMA element(s) of the above described embodiments of the linear actuator assembly are manufactured from a Shape Memory Alloy. The shape memory alloy is one of many different active materials. Accordingly, it should be appreciated that the SMA may include some other active material, such as but not limited to shape memory polymers

(SMP), piezoelectric materials, electroactive polymers (EAP), and ferromagnetic materials.

Suitable shape memory alloys can exhibit a one-way shape memory effect, an intrinsic two-way effect, or an extrinsic two-way shape memory effect depending on the alloy composition and processing history. The two phases that occur in shape memory alloys are often referred to as martensite and austenite phases. The martensite phase is a relatively soft and easily deformable phase of the shape memory alloys, which generally exists at lower temperatures. The austenite phase, the stronger phase of shape memory alloys, occurs at higher temperatures. Shape memory materials formed from shape memory alloy compositions that exhibit one-way shape memory effects do not automatically reform, and depending on the shape memory material design, will likely require an external mechanical force to reform the shape orientation that was previously exhibited. Shape memory materials that exhibit an intrinsic shape memory effect are fabricated from a shape memory alloy composition that will automatically reform themselves.

The temperature at which the shape memory alloy remembers its high temperature form when heated can be adjusted by slight changes in the composition of the alloy and through heat treatment. In nickel-titanium shape memory alloys, for example, it can be changed from above about 100° C. to below about −100° C. The shape recovery process occurs over a range of just a few degrees and the start or finish of the transformation can be controlled to within a degree or two depending on the desired application and alloy composition. The mechanical properties of the shape memory alloy vary greatly over the temperature range spanning their transformation, typically providing the shape memory material with shape memory effects as well as high damping capacity. The inherent high damping capacity of the shape memory alloys can be used to further increase the energy absorbing properties.

Suitable shape memory alloy materials include without limitation nickel-titanium based alloys, indium-titanium based alloys, nickel-aluminum based alloys, nickel-gallium based alloys, copper based alloys (e.g., copper-zinc alloys, copper-aluminum alloys, copper-gold, and copper-tin alloys), gold-cadmium based alloys, silver-cadmium based alloys, indium-cadmium based alloys, manganese-copper based alloys, iron-platinum based alloys, iron-platinum based alloys, iron-palladium based alloys, and the like. The alloys can be binary, ternary, or any higher order so long as the alloy composition exhibits a shape memory effect, e.g., change in shape orientation, damping capacity, and the like. For example, a nickel-titanium based alloy is commercially available under the trademark NITINOL from Shape Memory Applications, Inc.

As noted above, the control signal preferably includes an electrical signal for actuating the SMA element. However, it should be appreciated that if another active material is used, then the control signal may differ. For example, the control signal may alternatively include a heat signal, a magnetic signal, a pneumatic signal, a mechanical signal, and the like, and combinations comprising at least one of the foregoing signals, with the particular activation signal dependent on the materials and/or configuration of the active material.

The detailed description and the drawings or figures are supportive and descriptive of the invention, but the scope of the invention is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed invention have been described in detail, various alternative designs and embodiments exist for practicing the invention defined in the appended claims.

The invention claimed is:

1. A linear motion device comprising:

a rod extending along a longitudinal axis; and

a plurality of actuator units, with each of the plurality of actuator units including at least one Shape Memory Alloy (SMA) element attached to a coupler, wherein the at least one SMA element of each of the plurality of actuator units moves the coupler along the longitudinal axis and into grasping engagement with the rod to move the rod a unit movement distance along the longitudinal axis in response to a control signal;

wherein the plurality of actuator units are actuated repeatedly in a synchronous order to move the rod in a continuous linear motion a distance greater than the unit movement distance of each of the plurality of actuator units;

wherein each of the plurality of actuator units includes a first coupler and a second coupler disposed on opposite sides of the rod; and

wherein the at least one SMA element includes a connecting SMA element extending between and attached to both the first coupler and the second coupler and configured to contract to draw the first coupler and the second coupler together into grasping engagement with the rod in response to the signal.

2. A linear motion device as set forth in claim **1** wherein the at least one SMA element of each of the plurality of actuator units contracts in response to the control signal to move the coupler.

3. A linear motion device as set forth in claim **1** wherein the at least one SMA element of each of the plurality of actuator units elongates in response to the cessation of the control signal to release the coupler from the grasping engagement with the rod and allow the coupler to return to a neutral position.

4. A linear motion device as set forth in claim **1** wherein the at least one SMA element of each of the plurality of actuator units is operable to move the coupler and the rod in both a first direction parallel to the longitudinal axis, and a second direction parallel to the longitudinal axis, wherein the first direction is opposite the second direction.

5. A linear motion device as set forth in claim **4** wherein the at least one SMA element includes a first SMA element attached to the coupler for moving the coupler in the first direction, and a second SMA element attached to the coupler for moving the coupler in the second direction.

6. A linear motion device as set forth in claim **1** wherein each of the plurality of actuator units includes at least one spring.

7. A linear motion device as set forth in claim **1** wherein at least one of the rod and the coupler include a friction feature.

8. A linear motion device as set forth in claim **1** wherein each of the plurality of actuator units includes a housing, with the rod and the coupler moveable relative to the housing.

9. A linear motion device as set forth in claim **8** wherein the coupler is coupled to the housing.

10. A linear motion device as set forth in claim **1** wherein a first group of the plurality of actuator units may be actuated simultaneously to increase a moving force applied to the rod.

11. A linear motion device as set forth in claim **1** wherein the coupler includes a spring member.

12. A linear motion device as set forth in claim **1** wherein the coupler includes a lever arm.

13. A linear motion device as set forth in claim **1** wherein each of the plurality of actuator units may default to a normally engaged position disposed in grasping engagement with the rod, or a normally disengaged position not disposed in grasping engagement with the rod.

14. A linear actuator assembly for a linear motion device, the linear actuator assembly comprising:

a plurality of actuator units, with each of the actuator units including:

a housing;

a coupler; and

at least one Shape Memory Alloy (SMA) element attached to the coupler;

wherein the at least one SMA element moves the coupler from a neutral position along a longitudinal axis and into grasping engagement with a rod to move the rod a unit movement distance along the longitudinal axis in response to a control signal;

wherein the at least one SMA element of each of the plurality of actuator units contracts in response to the control signal to move the coupler; and

wherein the at least one SMA element of each of the plurality of actuator units elongates in response to the cessation of the control signal to release the coupler from the grasping engagement with the rod and allow the coupler to return to the neutral position;

wherein the plurality of actuator units are actuated repeatedly in a synchronous order to move the rod in a continuous linear motion a distance greater than the unit movement distance of each of the plurality of actuator units; and

wherein each of the plurality of actuator units includes a first coupler and a second coupler disposed on opposite sides of the rod, and wherein the at least one SMA element includes a connecting SMA element extending between and attached to both the first coupler and the second coupler and configured to contract to draw the first coupler and the second coupler together into grasping engagement with the rod in response to the signal.

15. A linear actuator assembly as set forth in claim **14** wherein each of the plurality of actuator units includes at least one spring.

16. A linear actuator assembly as set forth in claim **14** wherein each of the plurality of actuator units includes a housing, with the rod and the coupler moveable relative to the housing, and with the coupler coupled to the housing.

17. A linear actuator assembly as set forth in claim **14** wherein the at least one SMA element includes a first SMA element attached to the coupler for moving the coupler in a first direction parallel to the longitudinal axis, and a second SMA element attached to the coupler for moving the coupler in a second direction parallel to the longitudinal axis, wherein the first direction is opposite the second direction.

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